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Quality Assurance Audits of the EPA (Environmental Protection Agency) State-Operated Precipitation Collection Network: 1987

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QUALITY ASSURANCE AUDITS OF THE EPA STATE-OPERATED PRECIPITATION COLLECTION NETWORK: 1987

by

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16. ABSTRACT

The collection of precipitation and the measurement of its constituents are important steps in attaining a better understanding of the distribution and effects of acid rain in the United States.

This document is a report of the findings from quality assurance and technical assistance visits made in 1987 to the 29 sites that comprise the State Operated Precipitation Network. The network is staffed mainly by personnel from state environmental agencies and forestry commissions. It is under the overall sponsorship of regional and national offices of the Environmental Protection Agency.

Procedures followed in conducting the site visits are described. Results of systems and performance audits are discussed for siting, collection equipment, and field laboratories.

This report covers site visits made from May 1987 through October 1987.

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ABSTRACT

The collection of precipitation and the measurement of its constituents are important steps in attaining a better understanding of the distribution and effects of "acid rain" in the United States.

This document is a report of the findings from quality assurance and technical assistance visits made in 1987 to the 29 sites that comprise the State-Operated Precipitation Network. The network is staffed mainly by personnel from state environmental agencies and forestry commissions. It is under the overall sponsorship of regional and national offices of the Environmental Protection Agency.

Procedures followed in conducting the site visits are described. Results of systems and performance audits are discussed for siting, collection equipment, and field laboratories.

Where exceptions are found, the possible effects of nonstandard siting and improperly operating equipment on the data base are discussed. Recommendations are given for improvement and standardization of sites and the network as a whole.

Information from visits to the sites in 1985/86 are compared to the findings from the 1987 visits.

This report is submitted by Research Triangle Institute in partial fulfillment of EPA Contract Nos. 68-02-4125 and 68-D8-0001. This report covers site visits made from May 12, 1987 through October 16, 1987.

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SECTION 1
INTRODUCTION

This document is the summarizing report of quality assurance audits and technical assistance provided to the State-Operated Network of precipitation collection stations during survey visits made in the period May through October 1987. Table 1 lists the sites, their identification numbers, the names of each site's supervisor and operator, and the date of the site visit. Sites are arranged by identification number and are in alphabetical order by state. Figure 1 shows the locations of the sites on a map of the United States.

During the period covered by this report, the State-Operated Network consisted of 29 sites in EPA Regions III, IV, VI, and VIII that collect precipitation samples on a weekly basis. States or local government agencies sponsor the collection site and its operations and provide personnel. The EPA regional offices assist in site selection, operator training, data processing, coordination of the network, and fund the analysis of samples through a contracted central laboratory, Global Geochemistry, Corp., Canoga Park, CA. EPA-RTP provides a quality assurance site visitation program through a contract with Research Triangle Institute (RTI) (1). Data from the network are submitted to the Acid Deposition System (ADS) for Statistical Reporting, Battelle Pacific Northwest Laboratory, Richland, WA (2).

GOALS

The goals for the program of on-site quality assurance assistance to the sites in the State-Operated Network are to:

(1) Provide a qualitative assessment of each site and its surroundings, the operator's adherence to sample collection and analysis procedures, and the condition of the site's collection and analysis equipment through an on-site systems survey;

(2) Provide a quantitative assessment of the operation of the precipitation collector and the accuracy of response of field and laboratory measurement devices for precipitation depth, mass, temperature, conductivity, and pH through on-site performance tests;

(3) Provide technical assistance to the operator by verbal explanation, minor troubleshooting, calibration of equipment, and by making recommendations for corrective action;

(4) Submit brief reports for each site detailing site characteristics, results of quality assurance tests, and technical assistance provided;

(5) Document the locations of the sites and their surroundings by assembling a collection of site maps and color slides.

This report is divided into eight sections and two appendices. They are as follows:

Section	Topic
1	Introduction
2	Conclusions
3	Recommendations
4	Approach
5	Quality Assurance Audit Procedures
6	Results and Discussion - Collection Site - Field Laboratory - Siting Criteria
7	Comparison of 1987 and 1986 Audit Results
8	References
Appendix A	Siting Criteria for Urban-Influenced Wet Deposition Collection Sites
Appendix B	Siting Criteria for Regionally Located Wet Deposition Collection Sites

TABLE 1. STATE-OPERATED NETWORK SITES VISITED

Site Name	ID	Supervisor	Operator	Date of Site Visit
Mobile AL	0101	Ken Barrett	Kelly Williams	07/15/87
Tallassee AL	0102	Ken Barrett	Steve Taylor	07/16/87
Georgetown DE	0801	Joe Klimet	John Thomas	10/13/87
Lums Pond DE	0802	Joe Klimet	Alan Street	10/14/87
Hiawassee GA	1101	Chris Redmond	Roy Garrett	08/10/87
Summerville GA	1102	Chris Redmond	Laurie Koenig	08/11/87
Grant Forest GA	1103	Chris Redmond	Tammy Ramsey	08/13/87
Dawsonville GA	1104	Chris Redmond	Winston West	08/10/87
McDuffie County GA	1105	Chris Redmond	Pete Allen	08/12/87
Waycross GA	1106	Chris Redmond	Cliff Hargrove	08/14/87
Grayson Lake KY	1801	Jerry Sudduth	David Brokaw	09/21/87
Mammoth Cave KY	1802	Jerry Sudduth	Henry Holman	09/23/87
Rosepine LA	1901	Michael Hebert	Kenneth Johnson	05/13/87
Chase LA	1902	Michael Hebert	L. C. Ingles	07/14/87
Carville LA	1903	Michael Hebert	Michael Hebert	05/12/87
Rocky Gap MD	2101	Bob O'Melia	Dianne Franks	10/16/87
The Elms MD	2103	Bob O'Melia	Robert Judd	10/15/87
University MS	2501	Daryl Whittington	Randy Wolfe	07/13/87
Cape Romain SC	4201	Gene Slice	Lee Thomas	08/27/87
Congaree Swamp SC	4202	Gene Slice	Jim Jordan	08/26/87
Delta SC	4203	Gene Slice	Jim Jordan	08/25/87
Long Creek SC	4204	Gene Slice	George Tomlin	08/25/87
Custer State Park SD	4301	Neva Welch	Mickey Schlecht	09/30/87
Pierre SD	4302	Neva Welch	Neva Welch	09/29/87
Center Hill TN	4401	Gary Leggett	Mike Hale	09/25/87
Charleston WV	5001	Ron Engle	Gary McComas	09/29/87
Greenbrier WV	5002	Ron Engle	Gary McComas	09/28/87
Warwood WV	5003	Ron Engle	David DeWitt	09/30/87
New Manchester WV	5004	Ron Engle	David DeWitt	09/30/87

Figure 1. Locations of State-Operated Network Sites.

SECTION 2
CONCLUSIONS

The State-Operated Network is a weekly precipitation collection network of 29 sites located primarily in the eastern and southeastern United States. State agencies have provided personnel to service the sites and laboratories to analyze the samples and submit them to a central laboratory for further analysis. The site supervisors, operators, and analysts were found to be familiar with their duties, handled the precipitation samples carefully, analyzed the samples accurately in most cases, and seemed genuinely interested in the network and the data.

A number of the sites still need to be improved upon in terms of siting and maintenance of sample collection and analysis equipment. Emphasis should be placed on proper placement and operation of precipitation collectors, installation and proper operation of rain gauges, and standardization of field laboratory techniques.

Compared to results of the 1986 site visits, the 1987 data show significant improvements have been made in the accuracy of site pH and conductivity measurements; in the cleanliness of the collection bucket lid and the goodness of its seal against the collection bucket; and in satisfying the criteria for collector height above ground and in relation to the rain gauge. Several sites are still in need of modification in order to be removed from nearby obstructions.

SECTION 3
RECOMMENDATIONS

The following recommendations are drawn from those given in Section 6 of this report. The first four recommendations are the most important to institute.

1. Precipitation collector malfunctions. Repair or replace those collectors that were found to be malfunctioning. Particular attention should be given to the sensors that do not heat properly. In this way, the collection of wet-only samples is assured.

2. Sample collector relocation. Any sample collection equipment that is obstructed by trees or structures should be relocated so that the 45° projection angle and 30° arc siting criteria are satisfied. Rain gauges should be repositioned so that they are separated by at least 5 m (but no more than 30 m) from the collector, and so that their orifices are level and in the same plane (to ± 1 foot) as that of the collector bucket rim. The collector should be installed such that when the long axis of the collector is oriented west to east, the collector's wet-side bucket faces west.

3. Repair or acquire rain gauges. Inoperative rain gauges should be repaired and repositioned to meet siting criteria. Recording rain gauges should be acquired for those four sites that do not have them. Precipitation collectors should be electrically connected to the rain gauges so that their openings and closings can be noted as event marks on the rain gauge chart. Use the rain gauge chart and the event marker as a quality control tool to validate the proper operation of the collector. Periodic quality control checks should be made to ensure that the rain gauges are operating correctly and accurately.

4. Quality control check of sensor. There is still a need to institute a simple quality control check to be performed by the operator at least once per month to detect collector sensors that heat improperly so that corrective action can be taken.

5. Standardize field laboratory techniques. Field laboratory techniques and equipment should be standardized so that small volumes of samples are used to determine conductivity and pH. Site operators should abide by the guideline that requires that the central laboratory receive first priority in analysis of small-volume weekly samples.

6. Correct siting criteria variances. Other siting criteria variances not noted in (2) above should be corrected as funding and time allow.

SECTION 4
APPROACH

The following approach was utilized in preparing for and providing quality assurance assistance to agencies maintaining precipitation collection sites in the State-Operated Network.

First, pertinent network documents and reports were reviewed, and from them two questionnaires were prepared that are specific to the operation of the State-Operated Network. One questionnaire is used to conduct a systems and performance survey of the site and laboratory operations and the operator's adherence to designated procedures. The other questionnaire addresses siting criteria for either a regionally-located or an urban-influenced site. The systems and performance survey questionnaire can be found in the project work plan (1). The siting criteria questionnaires were given in the report of 1985/1986 Quality Assurance Audits and are illustrated for regionally-located and urban-located sites in Figures 2 and 3, respectively.

Second, in coordination with the EPA Project Officer, contact was made by telephone and letter with those persons whose sites were to be visited. Representatives from the EPA regional office, the state and/or local air quality organization, and, if applicable, the sponsoring agency were invited to be present along with the site supervisor and operator. The dates for the site visits were set, the itinerary planned, and information such as maps, source inventories, and photographs were acquired for study prior to the actual site visit. Source location "bulls-eye" maps were created from the 1980 NAPAP Emissions Inventory data base and used to verify the presence or absence of sources within a 50 km radius of the site. Figure 4 illustrates a typical emissions plot.

Third, the sites and field laboratories were visited and evaluated. During the visit, the questionnaires were completed and each site was documented by sketch, photographs, and by ascertaining its location on a map such as the USGS 1:24,000 series. A one-page brief site survey report of findings was completed and reviewed with the operator at the conclusion of the site visit. This report form is shown in Figure 5.

Fourth, a brief report of the visit was prepared for each site. These reports were reviewed by the EPA Project Officer, revised as appropriate, and sent to regional, state, and/or local officials responsible for the collection site.

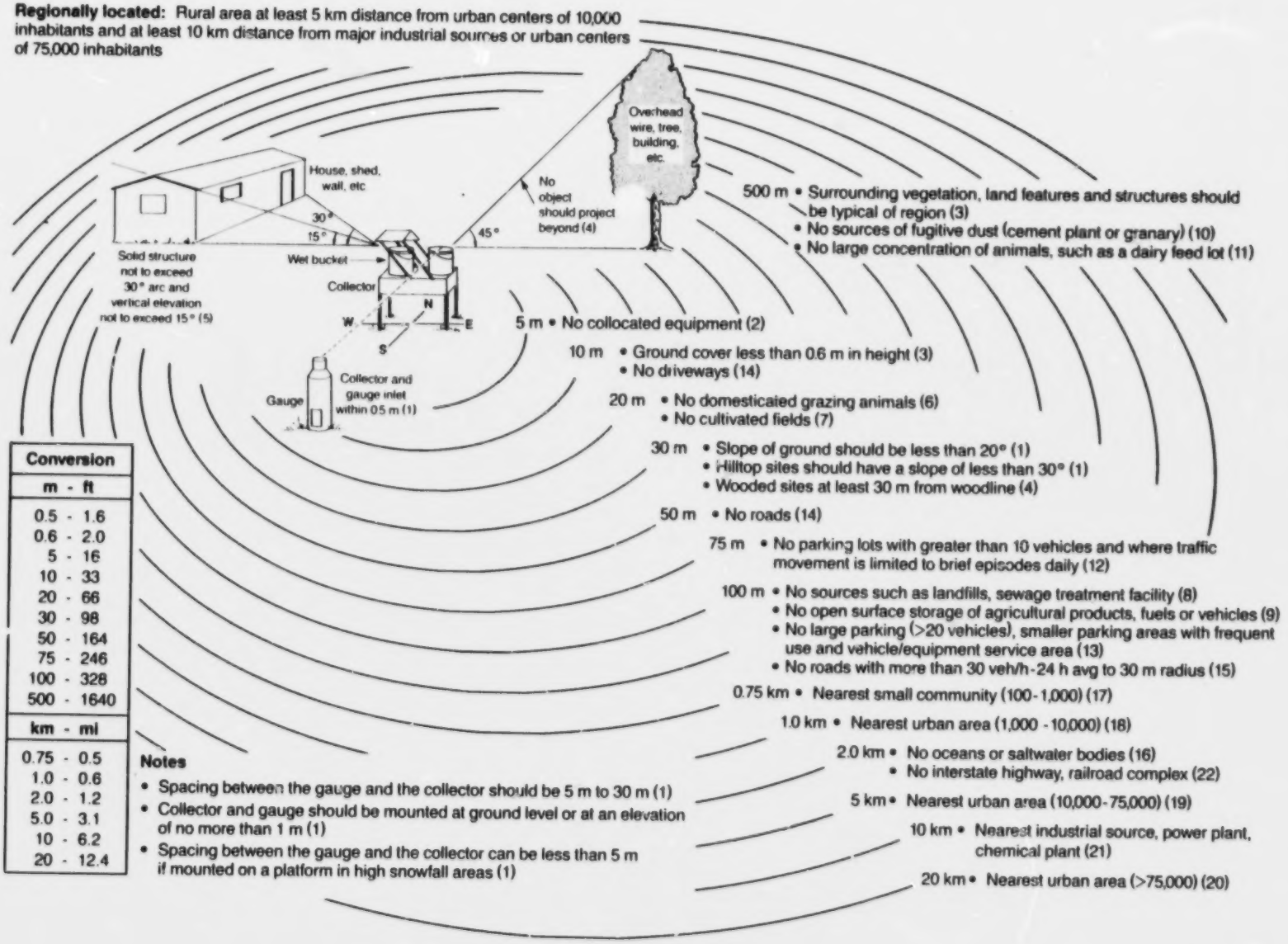
Regionally located: Rural area at least 5 km distance from urban centers of 10,000 inhabitants and at least 10 km distance from major industrial sources or urban centers of 75,000 inhabitants
Overhead wire, tree, building, etc.
House, shed, wall, etc
No object should project beyond (4)
30°
15°
45°
Solid structure not to exceed 30° arc and vertical elevation not to exceed 15° (5)
Wet bucket
Collector
N
W
E
S
Gauge
Collector and gauge inlet within 0.5 m (1)
500 m • Surrounding vegetation, land features and structures should be typical of region (3)
• No sources of fugitive dust (cement plant or granary) (10)
• No large concentration of animals, such as a dairy feed lot (11)
5 m • No collocated equipment (2)
10 m • Ground cover less than 0.6 m in height (3)
• No driveways (14)
20 m • No domesticated grazing animals (6)
• No cultivated fields (7)
30 m • Slope of ground should be less than 20° (1)
• Hilltop sites should have a slope of less than 30° (1)
• Wooded sites at least 30 m from woodline (4)
50 m • No roads (14)
75 m • No parking lots with greater than 10 vehicles and where traffic movement is limited to brief episodes daily (12)
100 m • No sources such as landfills, sewage treatment facility (8)
• No open surface storage of agricultural products, fuels or vehicles (9)
• No large parking (>20 vehicles), smaller parking areas with frequent use and vehicle/equipment service area (13)
• No roads with more than 30 veh/h-24 h avg to 30 m radius (15)
0.75 km • Nearest small community (100-1,000) (17)
1.0 km • Nearest urban area (1,000 - 10,000) (18)
2.0 km • No oceans or saltwater bodies (16)
• No interstate highway, railroad complex (22)
5 km • Nearest urban area (10,000-75,000) (19)
10 km • Nearest industrial source, power plant, chemical plant (21)
20 km • Nearest urban area (>75,000) (20)
Conversion
m - ft
0.5 - 1.6
0.6 - 2.0
5 - 16
10 - 33
20 - 66
30 - 98
50 - 164
75 - 246
100 - 328
500 - 1640
km - mi
0.75 - 0.5
1.0 - 0.6
2.0 - 1.2
5.0 - 3.1
10 - 6.2
20 - 12.4
Notes
• Spacing between the gauge and the collector should be 5 m to 30 m (1)
• Collector and gauge should be mounted at ground level or at an elevation of no more than 1 m (1)
• Spacing between the gauge and the collector can be less than 5 m if mounted on a platform in high snowfall areas (1)

Figure 2. Siting Criteria Diagram for Regionally Located State-Operated Precipitation Network Sites.

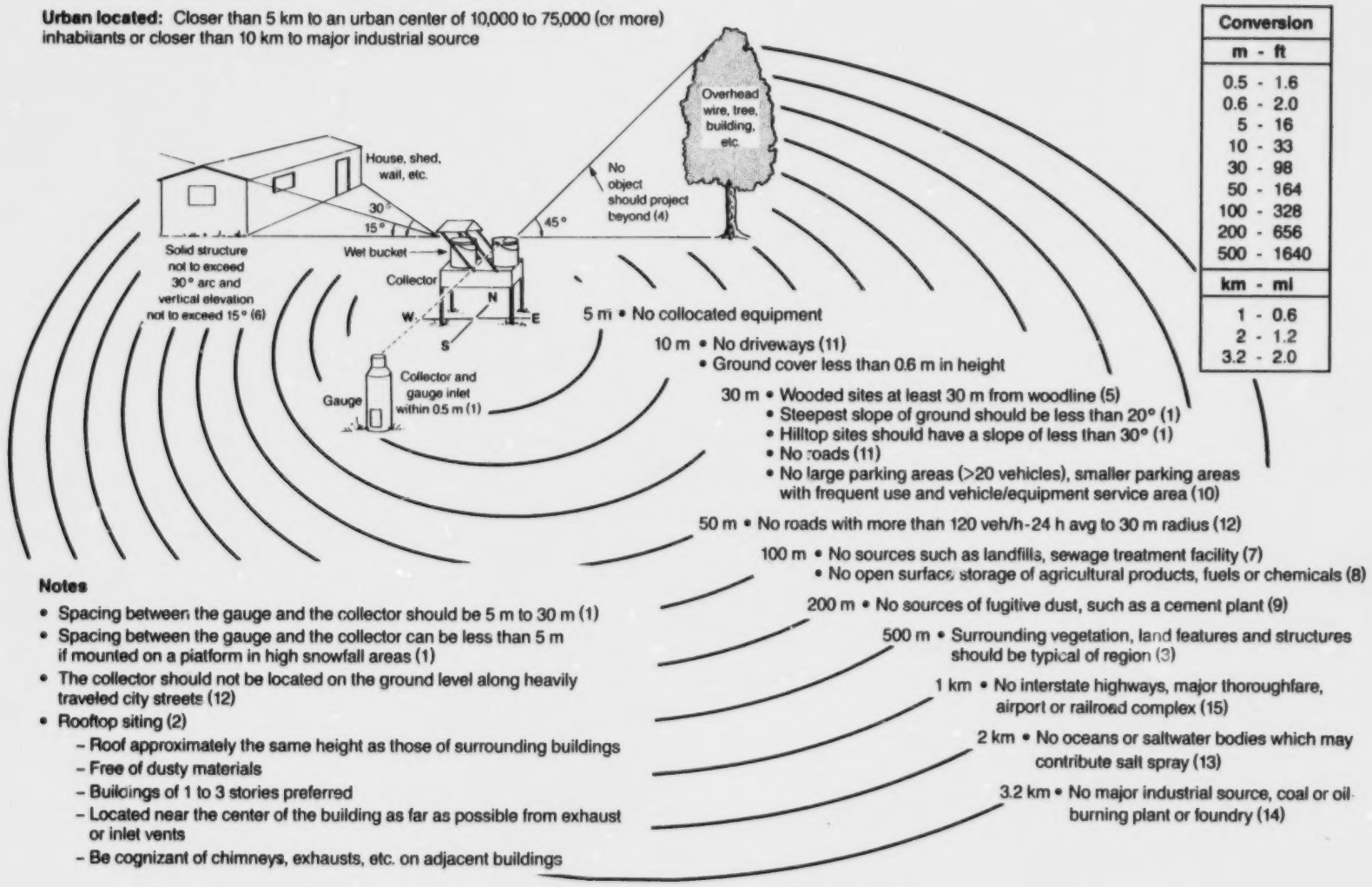
Urban located: Closer than 5 km to an urban center of 10,000 to 75,000 (or more) inhabitants or closer than 10 km to major industrial source
Overhead wire, tree, building, etc.
House, shed, wall, etc.
No object should project beyond (4)
30°
15°
45°
Solid structure not to exceed 30° arc and vertical elevation not to exceed 15° (6)
Wet bucket
Collector
W
N
E
S
Gauge
Collector and gauge inlet within 0.5 m (1)
5 m • No collocated equipment
10 m • No driveways (11)
• Ground cover less than 0.6 m in height
30 m • Wooded sites at least 30 m from woodline (5)
• Steepest slope of ground should be less than 20° (1)
• Hilltop sites should have a slope of less than 30° (1)
• No roads (11)
• No large parking areas (>20 vehicles), smaller parking areas with frequent use and vehicle/equipment service area (10)
50 m • No roads with more than 120 veh/h-24 h avg to 30 m radius (12)
100 m • No sources such as landfills, sewage treatment facility (7)
• No open surface storage of agricultural products, fuels or chemicals (8)
200 m • No sources of fugitive dust, such as a cement plant (9)
500 m • Surrounding vegetation, land features and structures should be typical of region (3)
1 km • No interstate highways, major thoroughfare, airport or railroad complex (15)
2 km • No oceans or saltwater bodies which may contribute salt spray (13)
3.2 km • No major industrial source, coal or oil burning plant or foundry (14)
Notes
• Spacing between the gauge and the collector should be 5 m to 30 m (1)
• Spacing between the gauge and the collector can be less than 5 m if mounted on a platform in high snowfall areas (1)
• The collector should not be located on the ground level along heavily traveled city streets (12)
• Rooftop siting (2)
– Roof approximately the same height as those of surrounding buildings
– Free of dusty materials
– Buildings of 1 to 3 stories preferred
– Located near the center of the building as far as possible from exhaust or inlet vents
– Be cognizant of chimneys, exhausts, etc. on adjacent buildings
Conversion
m - ft
0.5 - 1.6
0.6 - 2.0
5 - 16
10 - 33
30 - 98
50 - 164
100 - 328
200 - 656
500 - 1640
km - mi
1 - 0.6
2 - 1.2
3.2 - 2.0

Figure 3. Siting Criteria Diagram for Urban Located State-Operated Precipitation Network Sites.

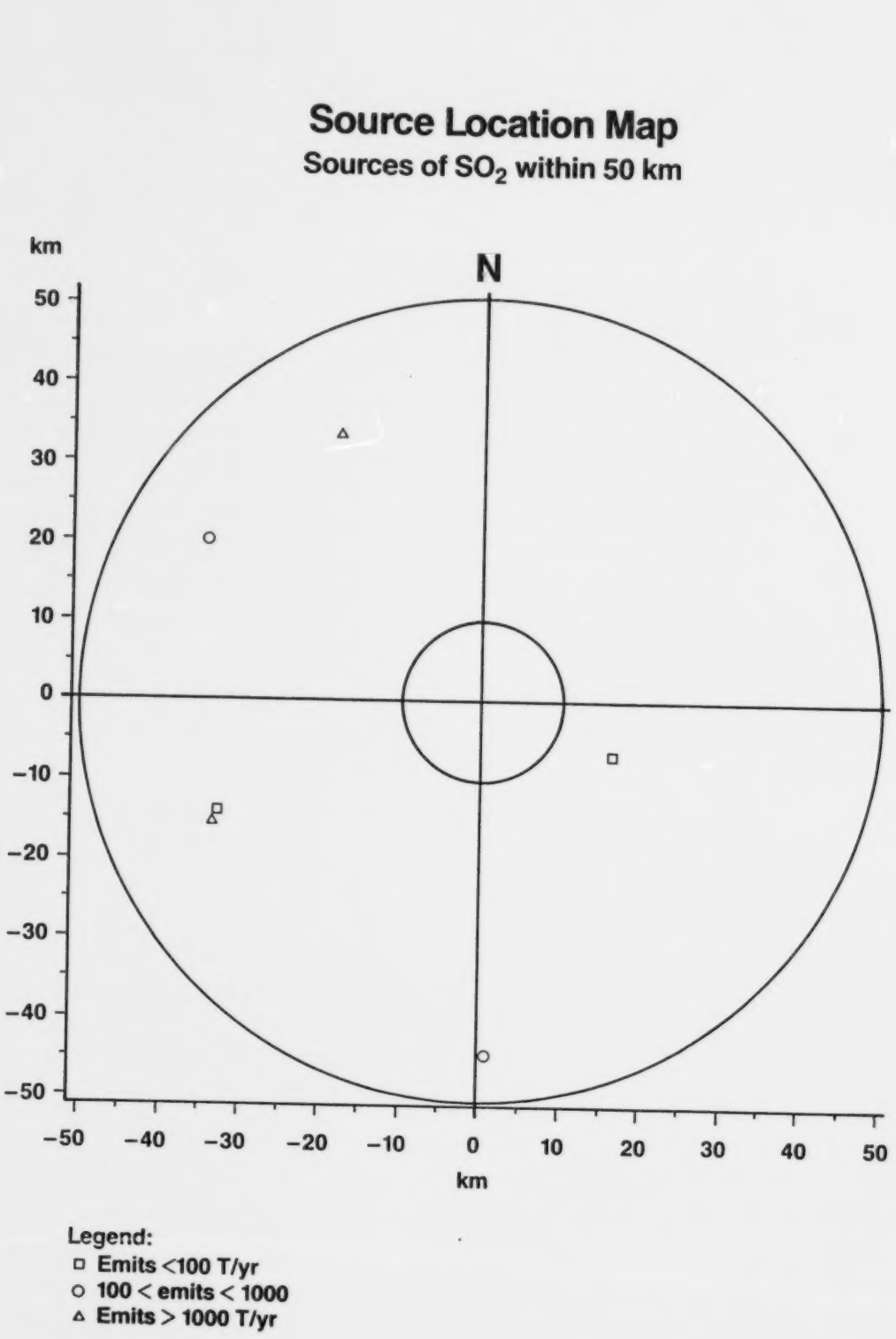

Figure 4. Source Location Map With Precipitation Site in Center.

EPA STATE-OPERATED NETWORK SITE VISITATION PROGRAM
Brief Site Survey Report Form

RTI Proj. _____

05/87 (Rev. 0)

A. Site Information

1. Site Name _____
2. Site Code _____
3. County _____ State _____
4. Supervisor's Name _____
5. Operator's Name _____
6. Operator address incorrect.
7. Date of visit _____ (m) _____ (d) _____ (y)
8. RTI Visitor's Name _____
9. RTI Notebook Number _____
10. Site location changed since last visit.
11. Regular operator not present.
12. Site supervisor not present.
13. Operating Agency _____
14. Other.

B. Siting Criteria

15. Collector on platform.
16. Wet bucket not west; sensor not north.
17. Ground cover, slope, or buffer zone.
18. Collector base is enclosed.
19. Objects >1 m high within 5 m.
20. Collector/gauge separation or height nonstandard.
21. Snow roof.
22. Vegetation higher than 2 feet.
23. 45° rule violated.
24. Storage or lots <100 m distant.
25. Animals or pasture <20 m. Feedlots <500 m.
26. Transportation sources <100 m.
27. Residential buildings outside 30° cone.
28. Industry <10 km distant (<20 km if upwind).
29. Site is urban influenced.
30. Other.

C. Equipment Summary

Precipitation Collector

44. Clutch tooth or collar worn.
47. Lid seal to wet bucket has gaps.
51. Sensor does not heat when activated.
53. Other.

Recording Rain Gauge

69. Gauge calibration out >0.1" (0 to 5")
70. Crossover point off >0.1".
71. Gauge calibration out >0.1" (5 to 12")
76. Other.

D. Sample Collection Procedures

78. Incomplete sampler servicing.
82. Other.

E. Field Laboratory Summary

Audit Test Solution No. _____

Conductivity Measurements

90. DI water > 10 μS/cm ± 3 μS/cm _____.
91. Check sample beyond outside ± 3 μS/cm limits[a] _____.
92. Site value, audit, _____ μS/cm.
93. Designated value, audit, _____ μS/cm.

pH Measurements

99. Check sample outside ± 0.1 pH limit[a] _____.
100. Site value, audit, _____ pH units.
101. Designated value, audit, _____ pH units.
103. Other.

[a]Note field and lab-supplied check samples.

F. Notes and Comments

Entry No.

_____ _____
_____ _____
_____ _____
_____ _____
_____ _____
_____ _____
_____ _____

Figure 5. Brief Site Survey Report Form for State-Operated Precipitation Network.

QUESTIONNAIRES

Two questionnaires were used during the site visits. The first was a field site systems and performance survey questionnaire that allows the site visitor to ask specific questions and record information concerning the following collection site features:

- the precipitation sampler
- the rain gauge
- sample collection and handling procedures
- the field laboratory, recordkeeping, and site notebook
- the pH meter
- the conductivity meter
- the balance.

The questionnaire contents are based on those features common to the National Atmospheric Deposition Program (NADP) and National Trends Network (NTN) precipitation collection networks. It may be found in the work plan for quality assurance assistance to the State-Operated Network (1). The EPA's "Quality Assurance Manual for Precipitation Measurement Systems" (3) was also used as a source of information. Additional questions are included concerning this network's use of plastic bag bucket liners and polyethylene bottles for shipping samples from the site to the central laboratory (4).

The second questionnaire concerns siting criteria. Depending on location, a questionnaire designed for either a regionally-located or an urban-influenced site was used. Information in the questionnaires is based on that given in three documents: the EPA "Quality Assurance Manual for Precipitation Measurements" (3), the U.S. Geological Survey document "Design of the National Trends Network for Monitoring the Chemistry of Acid Precipitation" (5), and the "NADP Instruction Manual: NADP/NTN Site Selection and Installation" (6). The siting criteria questionnaires were used to evaluate the suitability of each site in terms of:

- type and height of groundcover in the immediate vicinity of the proposed location of the sampling equipment (important to avoid sample contamination from the soil or plants)

- distance of the sample collector equipment from obstructions (important to avoid sample contamination and variation in sample catch efficiency)

- distance of the sample collection equipment from nearby and distant sources of contamination and pollution (important to avoid undue source influences on the sample's constituent concentrations which, if present, make the sample less representative of the region)

- human or animal activities in the vicinity of the collection site (important to avoid sample contamination)

- topographic, hydrologic, and orographic features of the land surrounding the site (important for regional representativeness, catch efficiency, avoidance of sample contamination, and desirable collector sensor operation).

SECTION 5
QUALITY ASSURANCE AUDIT PROCEDURES

This section discusses the audit procedures used during the quality assurance visits to the State-Operated Network sites.

RTI auditors accompanied the operator and others to each collection site and field laboratory with the dual aims of (1) documenting the site, its operation, and the accuracy of its instrument response to various quality assurance tests, and (2) providing information, training, and instruction for operators and supervisors, equipment calibration and minor maintenance as needed, and establishing contacts for further information and/or major repairs. A list of items checked is given in Table 2. All data from the site visit are recorded in a bound and numbered notebook. This notebook contains information concerning the site, a record of pre-trip confirmation of test solutions and audit devices, and the questionnaires. The original notebook is filed at RTI under a document control system.

SYSTEMS SURVEY

A quality assurance systems survey was conducted to quantitatively assess the site and its surroundings. One of two siting criteria questionnaires was employed, depending on whether the site was regionally-located or urban-influenced. The criteria address a site's spatial relationship to different types of sources and interferents which may cause precipitation collected at the site to be unrepresentative of the region. The factors determining the criteria include nearby point sources (e.g., industrial burners), line sources (e.g., roads), overhead obstructions to the collector (e.g., trees), and obstacles or land and aquatic features which may alter the wind patterns near the collector.

The operator's adherence to procedures specified in the site operator's instruction manuals (3,4,7) was also assessed. The operator demonstrated sample collection and analysis procedures which were observed, with special attention given to sample handling technique and calibration procedures. Site equipment was examined for proper installation and for signs of wear or faulty operation. It was noted whether solutions and equipment were properly stored. Site field reports and rain gauge charts were examined for legibility, completeness, and accuracy.

TABLE 2. LIST OF ITEMS CHECKED DURING SITE SURVEY VISIT

Precipitation Sampler

- lid/bucket seal
- sensor heater works
- clutch tension
- clutch wear
- winter problems
- proper counterbalance
- contamination by straps
- snow roof design, material, orientation
- level
- lid tension or drop
- bucket/sample handling
- orientation, height
- distance from other equipment

Supplies

- check inventory
- shortage
- excess
- plastic bag bucket liners

Mass

- accuracy of response
- calibration weight handling
- tolerance checks
- correct use of balance

Siting Characteristics

- distances from collector to:
  - other equipment
  - obstructions
  - roads, towns, cities
  - sources
- topographic features
- land use
- photographs, sketches

Precipitation Gauge

- winterization
- calibration of weight response
- cleanliness
- time calibration
- event marker working
- accuracy of chart reading ($\pm$ 0.1 inch)
- gauge data that is reported
- distance from other equipment
- height

pH Meter and Use

- accuracy of response
- no electrodes in bucket
- $\pm$ 0.2 pH unit agreement with test solution
- electrode condition
- electrode brand
- order of use
- use of pH check solution
- storage of buffers, check solutions

Conductivity

- accuracy of response
- no electrode in bucket
- use of 75 μmho/cm standard

Sample Collection Procedures

- bag liner changed after 7 days
- collector checked each Tuesday
- contamination checks

Information from the survey was entered in the systems and siting criteria questionnaires. Photographs (color prints) of the site were taken. The directions N, E, S, and W were photographed as viewed from the precipitation collector. The location of the site was marked on a map.

PERFORMANCE SURVEY

A quantitative performance survey was conducted at each site. Table 3 lists the equipment that was checked and the type of test used. Criteria for evaluating performance are specified in the EPA Quality Assurance Handbook (2, 8). Several items having to do with quality assurance test equipment materials and procedures are discussed below.

Precipitation Depth

The calibration of the Belfort recording rain gauge was checked over the range of 0 to 12 inches by use of the certified weight set (Number 8849 6P-1) obtained from Belfort Instrument Company. The certification of the weight set was checked by independently weighing the discs. In conducting the field check, the chart is first removed from the gauge and replaced with a new one. Next, the zero reading is established and then the weight discs are placed on the gauge to simulate precipitation in 1-inch increments from 1 to 12 inches. Gauge response is recorded in the notebook and on the chart.

If any reading was greater then $\pm$ 0.10 inch from the designated value, the gauge was calibrated (weather permitting) using the procedure given in the gauge manual (8). Check or calibration results were recorded in the questionnaire notebook.

Precipitation Collector

Several aspects of the precipitation collector were checked. Mechanical. The proper opening and closing cycle was checked by applying deionized water to the sensor and watching and timing the open-close cycle. Where applicable, wear on thrust collar indent and thrust tooth was visually checked. Where applicable, clutch pressure was checked by the mechanism's ability to lift 1640 g (two Belfort gauge weights). Tension on lid. This was checked in two ways: lifting the lid slightly through a spring scale and noting the tension required, and measuring the distance between the collector table top and the bottom edge of

TABLE 3. SITE MEASUREMENTS AND PERFORMANCE SURVEY METHODS

Site Measurement	Measurement Device	Performance Survey Method
Rain Depth	Rain Gauge	Challenge with known weights
Precipitation Sample Collection	Precipitation Collector	Measure resistance across sensor, measure tension and drop of bucket lid, measure temperature and voltage of activated sensor
Mass	Triple-beam Balance or equivalent	Challenge with traceable weights
pH	pH Meter and Electrode	Challenge with simulated precipitation sample of known pH
Conductivity	Conductivity Meter and Cell	Challenge with simulated precipitation sample of known conductivity

the lid with and without the collection bucket in place. Sensor. The sensor's cleanliness, proper voltages, electrical resistance at which the lid displaces, and heating (measured by a thermocouple placed against the sensor plate) were checked.

Mass

The accuracy of mass determination of the collection bucket contents was checked by having the operator weigh several Belfort rain gauge weights which had been calibrated against IOLM-certified brass weights.

pH and Conductivity

The accuracies of pH and conductivity measurements were checked by having the site operator analyze a simulated precipitation sample. This sample is a dilute solution of one of the EPA simulated precipitation reference materials which have been in use as quality assurance materials for several years. The concentrated solution was diluted and a portion checked in the RTI laboratory before being taken to the field.

The simulated precipitation test sample was given to the operator as a small aliquot. The test sample was not placed in a collection bucket or plastic bag, but rather was placed directly in the laboratory measurement vessel.

TECHNICAL ASSISTANCE

Technical assistance in the form of instruction, explanation, or demonstration, as needed to improve site performance, was provided. This assistance often included a discussion or demonstration of proper analytical techniques, instrument use, and calibration procedures. Operator questions were answered or referred to the proper program personnel.

In the event of an equipment deficiency at the site, the problem was identified, corrective action recommended, and the operator and supervisor were referred to others for additional information and guidance.

EXIT INTERVIEW

At the conclusion of the site survey, a short report (see Figure 5) of the visit was prepared and the results were discussed with the site operator and/or supervisor. During the exit interview, the operator and supervisor were given time to ask additional questions.

SECTION 6
RESULTS AND DISCUSSION

This section presents and discusses the results of systems and performance audits of the precipitation collection sites and field laboratories. Summarized first is information concerning the collection site equipment and its placement; second, information from the field laboratory; and third, information concerning siting criteria variances.

In each case, the desired or recommended value or condition is stated, the audit findings are given, and comments are made on whether or not the variance may affect the data.

COLLECTION SITE

Precipitation Collector System Checks

Systems checks were made of the precipitation collector. In 1987, the State-Operated Network had four different brands of collectors in use: Aerochem Metrics (ACM), N-CON, MIC, and Andersen (Anders.). Each is a wet-dry collector of similar design; thus, the systems checks generally apply to each brand. Table 4 lists the brand of collector at each site and the results of seven systems checks. The checks are explained and discussed below.

Height Standard. The collector should be installed on its standard 1-meter-high aluminum base. To prevent obstructions to windflow, the base should not be enclosed. Six of the 29 collectors were not at standard height. In all cases, this was due to their being on a platform or shelter roof. The Warwood and Charleston collectors were on the roofs of two-story buildings and met urban siting criteria. None of the collectors had the base enclosed.

Platform. In areas having an accumulation of over 0.5 meter of snow, the collector may be raised off the ground on a platform. The platform should be no higher than the maximum anticipated snow pack. For the most part, the platforms were short -- not more than 1 or 2 feet in height. The higher platforms (Rocky Gap, Cape Romaine, and Congaree Swamp) were necessary to raise the collector orifice above the level of a nearby earthen dam, a nearby monitoring shelter, and to prevent flooding at times of high water in the swamp, respectively. The effect of these platforms on the sample is believed to be minimal.

TABLE 4. PRECIPITATION COLLECTOR SYSTEM CHECKS

Site Name	Collector Type?	Height Standard?	Platform?	Wet Bucket Orientation	Distance from Rain Gauge (m)
Mobile AL	Anders.	Y (a)	N (a)	E	2.1
Tallassee AL	Anders.	Y	N	W	2
Georgetown DE	ACM	Y	N	E	7
Lums Pond DE	ACM	Y	N	W	7
Hiawassee GA	ACM	N	Y	S	1.8
Summerville GA	ACM	N	Y	E	1.9
Grant Forest GA	ACM	Y	N	W	5.3
Dawsonville GA	ACM	Y	N	W	5.5
McDuffie County GA	ACM	Y	N	SW	4
Waycross GA	ACM	Y	N	W	5.1
Grayson Lake KY	MIC	Y	N	N	8.4
Mammoth Cave KY	MIC	Y	N	W	9.2
Rosepine LA	ACM	Y	N	W	1.5
Chase LA	ACM	Y	N	N	2.3
Carville LA	ACM	Y	N	W	1.5
Rocky Gap MD	ACM	Y	Y	N	3
The Elms MD	ACM	Y	Y	NNW	2.7
University MS	ACM	Y	N	W	7.5
Cape Romain SC	ACM	N	Y	W	1.5
Congaree Swamp SC	ACM	N	Y	SW	0.5
Delta SC	MIC	Y	Y	NW	5
Long Creek SC	MIC	N	Y	SW	4
Custer State Park SD	ACM	Y	N	SE	5.8
Pierre SD	ACM	Y	N	NW	2.6
Center Hill TN	MIC	Y	N	N	15.2
Charleston WV	N-Con	Y	(b)	NNE	(c)
Greenbrier WV	Anders.	N	(b)	N	(c)
Warwood WV	N-Con	Y	(b)	S	(c)
New Manchester WV	N-Con	Y	(b)	N	(c)

(a) Y symbol means "yes"; N symbol means "no".
(b) Charleston and Warwood sites on rooftop; Greenbrier and New Manchester on roof of monitoring shelter.
(c) No recording rain gauge or event recorder at this site.

TABLE 4. PRECIPITATION COLLECTOR SYSTEM CHECKS, CONTINUED

Site Name	Collector Connected to Event Marker?	Height Correct With Respect To Rain Gauge?	Cover Seats Properly On Wet Bucket?
Mobile AL	Y (a)	Y	Y
Tallassee AL	Y	Y	Y
Georgetown DE	Y	Y	Y
Lums Pond DE	Y	Y	Y
Hiawassee GA	Y	N (a)	Y
Summerville GA	Y	Y	Y
Grant Forest GA	Y	Y	Y
Dawsonville GA	Y	Y	Y
McDuffie County GA	Y	Y	Y
Waycross GA	Y	Y	Y
Grayson Lake KY	Y	Y	Y
Mammoth Cave KY	Y	Y	Y
Rosepine LA	Y	Y	Y
Chase LA	Y	Y	Y
Carville LA	Y	Y	Y
Rocky Gap MD	Y	Y	Y
The Elms MD	Y	Y	Y
University MS	Y	Y	Y
Cape Romain SC	N	Y	Y
Congaree Swamp SC	N	Y	Y
Delta SC	N	Y	Y
Long Creek SC	N	Y	N
Custer State Park SD	Y	Y	Y
Pierre SD	Y	Y	Y
Center Hill TN	Y	N	Y
Charleston WV	(b)	(b)	Y
Greenbrier WV	(b)	(b)	Y
Warwood WV	(b)	(b)	Y
New Manchester WV	(b)	(b)	Y

(a) Y symbol means "yes"; N symbol means "no".
(b) No recording rain gauge or event marker at this site.

For those collectors located on the tops of monitoring sites or buildings (Greenbrier, New Manchester, Charleston, and Warwood), it is not clear what the effect may be. If the collectors were placed near ground level at the West Virginia sites, platforms would probably still be required due to the snow.

Wet Bucket Orientation. The collector should be mounted level with the wet side bucket to the west and the sensor facing north. In this way, the wet bucket is generally upwind of the dry side bucket (winds generally being from the S to SW in the eastern United States), and the sensor is downwind of the wet side bucket. This placement is designed to lessen the chance for contamination and to minimize obstruction to sample entry by the collector itself.

Fifteen of the 29 collectors are correctly installed with the wet bucket facing to the SW, W, or NW. Two are installed with the wet bucket facing S. These southerly installations probably have no effect on the data. The twelve collectors that are installed with the collection bucket facing N or E may cause an aberration in the collection efficiency or sample chemistry. It is recommended that all collectors be oriented with the wet bucket facing W and the sensor facing N. The date this change occurs must be documented and accompany the data base. This arrangement is not possible with the Andersen sampler since the sensor faces south when the wet bucket is oriented to the west.

Distance from Rain Gauge. The collector should be located within a distance of 30 m of the rain gauge but no closer than 5 m. This guideline is set so that the collector and gauge "see" the same precipitation event, and so that neither piece of equipment offers an aerodynamic interference to the other's collection ability.

Of the 25 sites that have collocated rain gauges (West Virginia sites do not have them), 14 were closer to the precipitation collector than the prescribed 5 meters. Of the 14 that were too close, three were tipping bucket rain gauges. Because the volume they displace is small compared to the larger Belfort weighing rain gauges, the effect of being closer than 5 meters is thought to be negligible. The other gauges that were too close should be moved further away if possible. These moves must be documented and noted in the data record through the Acid Deposition System (ADS) of data tabulation and retrieval.

It is again recommended that those sites having no rain gauges acquire them. The rain gauge gives an important record and is invaluable as a quality control tool for checking and recording (through an event marker) the proper operation of the precipitation collector.

Collector Connected to Event Marker. To assess the proper operation of the collector, a switch should be included in its mechanism to send a signal to an event marker to signal the opening and closing of the wet side bucket. It is convenient to have this record on the rain gauge chart.

Eight of the sites lack such a feature. Four of these eight have no rain gauge present. It is recommended that these sites acquire event marker capability, preferably on the rain gauge chart.

Height Correct with Respect to Rain Gauge. The heights above ground of the collection bucket and the rain gauge orifices should be within 1 foot of each other.

Two of twenty-five sites did not meet this criteria. In one of these cases (Hiawassee), the relative heights were very close to meeting the criteria, and the effect on the data is expected to be negligible. If the collector and/or gauge are repositioned in the future, this could be corrected and documented at that time. The Center Hill's tipping bucket gauge is mounted on a meteorological tower 25 feet above the collector.

Cover Seats Properly on Wet Bucket. The collector's bucket cover should fit tightly and evenly on the rim of the wet (and dry) bucket so that dust cannot enter during dry periods (and so that the cover is protected during wet periods). All covers seated properly.

Precipitation Collector Performance Checks

Table 5 lists the results of six performance checks conducted on the precipitation collectors. Not all checks were carried out on all collectors since the checks were designed for the Aerochem Metrics collector and there was concern that certain tests might affect the adjustments of the other brands of collectors. The tests and results are discussed below.

Lid Tension. The force that the bucket cover exerts against the rim of the collection bucket may be assessed by lifting the lid slightly above the bucket and reading the force (in grams) required to do so. A spring scale is used. Generally, tensions of 1500 g or greater are found for the Aerochem Metrics brand. Two of 21 collectors checked had lid tensions less than 1500 g. It should be noted that each of these was a brand other than Aerochem Metrics and the covers seated properly on the wet buckets. Whether or not these lower tensions are significant is not known.

TABLE 5. PRECIPITATION COLLECTOR PERFORMANCE CHECKS

Site Name	Lid Tension (g)	Lid Drop Distance (mm)	Ambient Grid Temp (C)	Grid Temp After Activation (C)	Liner Condition	Resistance To Activate Sensor (Kohms)
Mobile AL	^	^	31	63	Good	9990
Tallassee AL	^	^	31	44	Good	9990
Georgetown DE	3500	9	44	44	Good	78.5
Lums Pond DE	2000	^	80	80	3	^
Hiawassee GA	2800	10	43	55	Good	80
Summerville GA	3000	12	36	61	Good	85
Grant Forest GA	2800	10	100	100	Good	78
Dawsonville GA	3000	12	47	60	Good	86
McDuffie County GA	2600	10	35	^	Good	82
Waycross GA	2400	12	39	54	Good	89
Grayson Lake KY	1800	^	34	65	Good	10.1
Mammoth Cave KY	1400	16	54	64	Good	10
Rosepine LA	2200	6	30	61	Good	76
Chase LA	^	^	31	31	Good	76
Carville LA	2500	13	112	112	Good	82
Rocky Gap MD	3500	12	30	52	Good	69.5
The Elms MD	^	12	28	55	Good	71
University MS	2500	^	49	49	Good	80
Cape Romain SC	1800	7	34	34	Good	78
Congaree Swamp SC	1800	9	26	46	Good	80
Delta SC	1800	13	34	38	Good	^
Long Creek SC	^	^	43	40	Good	^
Custer State Park SD	2200	6	15	74	Good	83
Pierre SD	2500	18	20	60	Good	79.7
Center Hill TN	1200	^	38	38	Good	10
Charleston WV	^	10	42	42	Good	^
Greenbrier WV	>5000	7	30	84	Good	9990
Warwood WV	^	10	33	33	3	320
New Manchester WV	^	6	27	27	3	5300

Liner condition: 1=Split polyurethane, 2=Degraded polyurethane, 3=Dirt/mildew

^ means not checked or could not be determined. Some collectors had lids that were not amenable to the lid drop test and sensors that were not amenable to the resistance test.

Lid drop distance. Another measure of adequate lid/bucket seal tension is the lid drop distance -- the distance the lid drops when the wet bucket is momentarily removed. The Central Analytical Laboratory (Illinois State Water Survey) of the NADP/NTN network has found that a distance of 3 mm or greater is required to give tight, dust-free seals with the Aerochem Metrics collector. Of 16 collectors tested, all had 6 mm or greater lid drop distances. One of the two collectors with low lid tension (as measured by the spring scale) had a 16 mm lid drop distance; the other collector was not tested.

Ambient sensor grid temperatures. Generally, the temperature of the precipitation collector sensor is at ambient level when there is no precipitation. If the air temperature is below 4°C, the sensor heater (of the Aerochem Metrics) is set to come on, at a lower power level, to melt ice or snow that may fall. A sensor should not be heating at high temperatures (50°C or higher) unless it is raining. If it is heating, light rainfall striking the sensor may evaporate before a sufficient amount can accumulate, complete the circuit, and open the lid.

Three of the 29 sensors were found to be heating at temperatures considerably above ambient when no rain was falling. Sensors at Lum's Pond, Grant Forest, and Carville should be repaired. The Greenbrier and Charleston N-CON collectors are apparently set to heat at all times.

Sensor grid temperature five minutes after activation. There were a number of problems with the temperature of the activated sensors: eight sensors heated at all times (at a temperature either too hot or too cool); five sensors did not heat at all; 9 sensors heated, but the temperature attained was lower than 50°C.

Site Name	Not Heating	Heats at All Times	Temperature Too High	Temperature < 50°C
Mobile				
Tallassee	x			x
Lum's Pond		x	x	
Hiawassee	x			
Dawsonville	x			
McDuffie Co.				
Grayson Lake			x	
Mammoth Cave		x	x	
Chase				x
Carville		x		
Rocky Gap				x
Cape Romain	x			
Congaree Swamp	x			
Delta		x		x
Long Creek				x

Site Name	Not Heating	Heats at All Times	Temperature Too High	Temperature < 50°C
Charleston		x		x
Greenbrier		x		x
New Manchester		x		x
Warwood		x		x

Of these problems, the most serious are sensor not heating (will cause collector to stay open too long following a precipitation event; dust may get into sample); sensor on at all times and too high (may fail to open in light rain due to excessively fast evaporation; potential for excessive number of openings and closings during light precipitation); and temperature too low (this is expected to be more of a problem at sites where the ambient temperatures are quite cold in the winter, such as at the four in West Virginia).

It was recommended that the nonheating or overheating sensors be repaired or replaced. The McDuffie County sensor was wired incorrectly and was repaired at the time of the site visit.

Liner Condition. Most of the plastic liners were in good condition. Three had mold or mildew on the undersides. It was recommended that this be removed by wiping with deionized water and a laboratory tissue.

Resistance to activate sensor. Sensors activated at a median resistance of 80 Kohms. Three sites (Grayson Lake, Mammoth Cave, and Center Hill) required a very low resistance. Four sites (Mobile, Tallassee, Greenbrier, and New Manchester) had a very high resistance. The collector sensors' very low resistance requirements were all associated with the MIC-type collector. Three of the very high resistance sensors were the Andersen brand; one was the N-CON brand. Because these sensor resistances are so extraordinarily different from the ACM sensor, it is recommended that they be adjusted to activate at resistances of 70 to 80 Kohms. The low resistance sensors may not activate at the desired times; the high resistance sensors may activate too often, or in response to leaves or insects.

Rain Gauge System Checks

Results of six system checks of the installation and operation of the rain gauges are shown in Table 6. The four sites in West Virginia are not shown since they do not have rain gauges. Seven sites use tipping bucket gauges; 18 sites use the Belfort weighing rain gauge. All gauges were level and installed

TABLE 6. RAIN GAUGE SYSTEM CHECKS

Site Name	Type Gauge	Gauge Level?	Gauge Stable?	Gauge Top 1.5 m Above Ground?	Winterized?	Time Correct?	Event Marks Made?
Mobile AL	B	Y (a)	Y	Y	N (a)	Y	Y
Tallassee AL	B	Y	Y	Y	N	Y	Y
Georgetown DE	B	Y	Y	Y	Y	Y	Y
Lums Pond DE	B	Y	Y	^ (a)	N	Y	N
Hiawassee GA	B	Y	Y	N	N	Y	Y
Summerville GA	B	Y	Y	N	N	Y	Y
Grant Forest GA	B	Y	Y	Y	N	Y	Y
Dawsonville GA	B	Y	Y	Y	N	Y	N
McDuffie County GA	B	Y	Y	Y	N	Y	Y
Waycross GA	B	Y	Y	Y	N	Y	Y
Grayson Lake KY	C	Y	Y	Y	(b)	^	Y
Mammoth Cave KY	C	Y	Y	Y	(b)	^	Y
Rosepine LA	B	Y	Y	Y	N	Y	Y
Chase LA	B	Y	Y	Y	N	Y	Y
Carville LA	B	Y	Y	Y	N	Y	Y
Rocky Gap MD	B	Y	Y	^	Y	Y	Y
The Elms MD	B	Y	Y	Y	Y	Y	Y
University MS	B	Y	Y	Y	N	Y	N
Cape Romain SC	W	Y	Y	^	(b)	^	^
Congaree Swamp SC	W	Y	Y	^	(b)	^	^
Delta SC	C	Y	Y	N	(b)	^	^
Long Creek SC	C	Y	Y	N	(b)	^	^
Custer State Park SD	B	Y	Y	Y	Y	Y	Y
Pierre SD	B	Y	Y	Y	Y	^	Y
Center Hill TN	C	Y	Y	N	(b)	^	^

(a) Y symbol means "yes"; N symbol means "no"; ^ symbol means not applicable or not checked.
(b) Not applicable: tipping bucket rain gauge.

Type Gauge: B=Belfort, C=Climatronics, and W=Weathertronics. West Virginia sites are not listed since they do not have collocated rain gauges.

in a stable manner. The reason for several gauge openings not being 1.5 meters above ground is that these gauges are mounted on platforms. Event marks (corresponding to opening and closing of the precipitation collector) were not being made at the Lum's Pond, Dawsonville, and University sites. It was recommended that repairs be made.

Rain Gauge Performance Checks

Quantitative performance checks were conducted at 16 of the 18 sites that use Belfort rain gauges. Rain prevented the audits of two gauges. The quantitative performances of the tipping bucket gauges were not checked. Results are given in Table 7. Thirteen of the gauges were within the accuracy goal of $\pm$ 0.1 inch agreement with the audit value over the entire 0 to 12 inch range. Three varied by $>\pm$ 0.1 inch; however, for two of these the variation occurred at depths of 6 inches or greater, a seldom used range. Each of the out-of-calibration gauges were readjusted to bring them into $\pm$ 0.1 inch agreement over the entire 0 to 12 inch range.

Only the Rocky Gap, MD gauge was out-of-calibration at depths below six inches. Values for the Rocky Gap gauge are low by about 0.14 inch over the range 2 through 5 inches. It is still recommended that site operators obtain and use (twice a year) accurately weighed bottles of sand or water to check the performance of the rain gauges.

Sample Collection Procedures

Site operators were asked four questions concerning collection of the sample. Results are summarized in Table 8. Did the operator approach the collector from downwind? This is to prevent dust or hair from blowing off the operator into the bucket. Is the liner of the bucket changed after 7 days? A sample should be collected weekly. The bag liner in the bucket should be changed weekly even if no precipitation has occurred. Is the collector checked on Tuesday? For uniformity across the network and for comparison to other networks, the designated sample retrieval day is Tuesday. Also at this time the collector and rain gauge should be checked for proper operation. Is the bucket checked for contamination? The person who removes the sample from the collector should visually check it at the time of removal. Small dust particles or bird droppings may dissolve and not be noted a day or so later in the laboratory. These observations should be entered on the sample report form.

TABLE 7. RAIN GAUGE PERFORMANCE CHECKS

Site Name	Depth At Which Check Exceeds +/- 0.1 Inch Agreement											
	1	2	3	4	5	6	7	8	9	10	11	12
Mobile AL	-	-	-	-	-	-	-	-	-	-	-	-
Tallassee AL	-	-	-	-	-	-	-	-	-	-	-	-
Georgetown DE	-	-	-	-	-	x	x	x	x	x	x	-
Lums Pond DE	-	-	-	-	-	-	-	-	-	-	-	-
Hiawassee GA	-	-	-	-	-	-	-	-	-	-	-	-
Summerville GA	-	-	-	-	-	-	-	-	-	-	-	-
Grant Forest GA	-	-	-	-	-	-	-	-	-	-	-	-
Dawsonville GA	-	-	-	-	-	-	-	-	-	-	-	-
McDuffie County GA	-	-	-	-	-	-	-	-	-	-	-	-
Waycross GA	-	-	-	-	-	-	-	x	x	x	x	x
Rosepine LA	-	-	-	-	-	-	-	-	-	-	-	-
Chase LA	-	-	-	-	-	-	-	-	-	-	-	-
Carville LA	-	-	-	-	-	-	-	-	-	-	-	-
Rocky Gap MD	-	x	x	x	x	-	x	x	x	x	-	-
The Elms MD	-	-	-	-	-	-	-	-	-	-	-	-
University MS	-	-	-	-	-	-	-	-	-	-	-	-

Key: - = OK x = outside +/- 0.1 inch

TABLE 8. SAMPLE COLLECTION PROCEDURES

Site Name	Operator Approach From Downwind?	Bucket Changed After 7 Days?	Collector Checked On Tuesday?	Bucket Checked For Contamination?
Mobile AL	Y (a)	Y	Y	Y
Tallassee AL	Y	Y	Y	Y
Georgetown DE	N (a)	N	Y	Y
Lums Pond DE	Y	Y	Y	Y
Hiawassee GA	Y	Y	Y	Y
Summerville GA	Y	Y	Y	Y
Grant Forest GA	Y	Y	Y	Y
Dawsonville GA	Y	Y	Y	Y
McDuffie County GA	Y	Y	Y	Y
Waycross GA	Y	Y	Y	Y
Grayson Lake KY	Y	Y	Y	Y
Mammoth Cave KY	Y	Y	Y	Y
Rosepine LA	Y	Y	Y	Y
Chase LA	Y	Y	Y	Y
Carville LA	Y	Y	Y	Y
Rocky Gap MD	Y	Y	Y	Y
The Elms MD	Y	Y	Y	Y
University MS	Y	Y	Y	Y
Cape Romain SC	Y	Y	Y	Y
Congaree Swamp SC	Y	Y	Y	Y
Delta SC	Y	Y	Y	Y
Long Creek SC	Y	Y	Y	Y
Custer State Park SD	Y	Y	Y	Y
Pierre SD	Y	Y	Y	Y
Center Hill TN	N	Y	Y	Y
Charleston WV	Y	Y	Y	Y
Greenbrier WV	Y	Y	Y	Y
Warwood WV	Y	Y	Y	Y
New Manchester WV	Y	Y	Y	Y

(a) Y symbol means "yes"; N symbol means "no".

All operators were using proper sample collection procedures, and no instances of contamination were noted. Only one operator left the sample bucket and liner in the collector more than 7 days if no rain had occurred. Protocol calls for the bag liner to be removed and replaced with a new one if no rain occurs for a week.

FIELD LABORATORY

Systems Check of Field Laboratory

The laboratories that support the field collection sites are generally state or county laboratories and have adequate space, are clean, and are temperature-controlled. Answers to five questions concerning the operation of the field laboratory are given in Table 9.

Several laboratories serve more than one site. The South Carolina Department of Environmental Health and Control Laboratory in Columbia performs the field measurements on samples from the four South Carolina sites. The West Virginia Air Pollution Control Commission's laboratory in Charleston serves the Charleston and Greenbrier sites. A branch laboratory of the Commission in Warwood, WV serves the Warwood and New Manchester sites. Similarly, the state of Delaware laboratory analyzes samples for both the Georgetown and Lum's Pond sites.

Most of the laboratories handle the samples in a prompt manner and keep annotated records. Only one site was taking longer than 3 days before mailing samples to the network's central laboratory; the samples were being mailed within one week.

It is important to note that during part of 1987, the West Virginia sites were not sending their samples to the network's central laboratory. Instead, the samples were analyzed at the Charleston and Warwood laboratories.

It was not possible to check the rain depth charts at all sites. Several sites send the charts to a central point for review and archival. The two Kentucky sites use strip chart recorders, and the four West Virginia sites do not use recording rain gauges.

Conductivity. Table 10 lists answers to five items that relate to techniques used for conductivity measurements. Few of the site laboratories use the small YSI conductivity cell and thus cannot use the cell in an inverted position to economize on sample volume.

TABLE 9. SYSTEMS CHECK OF FIELD LABORATORY

Site Name	Adequate Space?	Laboratory Clean?	Laboratory Temperature Controlled?	Samples Shipped In 3 Days?	Rain Gauge Chart Annotated?
Mobile AL	Y (a)	Y	Y	Y	Y
Tallassee AL	Y	Y	Y	Y	Y
Georgetown DE	Y	Y	Y	Y	^ (a)
Lums Pond DE	Y	Y	Y	Y	^
Hiawassee GA	Y	Y	Y	Y	^
Summerville GA	Y	Y	Y	Y	^
Grant Forest GA	Y	Y	Y	Y	N (a)
Dawsonville GA	Y	Y	Y	Y	^
McDuffie County GA	Y	Y	Y	Y	N
Waycross GA	Y	Y	Y	N	Y
Grayson Lake KY	Y	Y	Y	Y	^
Mammoth Cave KY	Y	Y	Y	Y	^
Rosepine LA	Y	Y	Y	Y	Y
Chase LA	Y	Y	Y	Y	Y
Carville LA	Y	Y	Y	Y	Y
Rocky Gap MD	Y	Y	Y	Y	Y
The Elms MD	Y	Y	Y	Y	Y
University MS	Y	Y	Y	Y	Y
Cape Romain SC	Y	Y	Y	Y	Y
Congaree Swamp SC	Y	Y	Y	Y	Y
Delta SC	Y	Y	Y	Y	^
Long Creek SC	Y	Y	Y	Y	Y
Custer State Park SD	Y	Y	Y	Y	Y
Pierre SD	Y	Y	Y	Y	Y
Center Hill TN	Y	Y	Y	Y	^
Charleston WV	Y	Y	Y	Y(b)	^
Greenbrier WV	Y	Y	Y	Y(b)	^
Warwood WV	Y	Y	Y	Y(b)	^
New Manchester WV	Y	Y	Y	Y(b)	^

(a) Y symbol means "yes"; N symbol means "no"; ^ symbol means not applicable or not checked.
(b) West Virginia sites shipped samples to the state laboratory.

TABLE 10. CONDUCTIVITY MEASUREMENT TECHNIQUE

Site Name	Inverted Cell Technique	Standard Tested Before H2O	Distilled Water Rinse	Sample Rinse	Conductivity Values Corrected
Mobile AL	Y (a)	Y	Y	Y	Y
Tallassee AL	N (a)	Y	Y	Y	Y
Georgetown DE	^ (a)	^	^	^	^
Lums Pond DE	^	^	^	^	^
Hiawassee GA	Y	Y	Y	N	Y
Summerville GA	Y	Y	Y	N	Y
Grant Forest GA	N	Y	Y	N	Y
Dawsonville GA	N	Y	Y	Y	Y
McDuffie County GA	N	Y	Y	Y	Y
Waycross GA	N	Y	Y	Y	Y
Grayson Lake KY	Y	Y	Y	Y	Y
Mammoth Cave KY	Y	Y	Y	Y	Y
Rosepine LA	N	Y	Y	N	Y
Chase LA	N	N	Y	Y	Y
Carville LA	Y	Y	Y	N	Y
Rocky Gap MD	N	Y	Y	Y	Y
The Elms MD	N	Y	Y	Y	Y
University MS	N	Y	Y	Y	Y
Cape Romain SC	N	Y	Y	Y	Y
Congaree Swamp SC	N	Y	Y	Y	Y
Delta SC	N	Y	Y	Y	Y
Long Creek SC	N	Y	Y	Y	Y
Custer State Park SD	N	Y	Y	Y	Y
Pierre SD	N	Y	Y	Y	Y
Center Hill TN	Y	Y	Y	Y	Y
Charleston WV	N	Y	Y	Y	Y
Greenbrier WV					
Warwood WV	N	Y	Y	Y	N
New Manchester WV	N	Y	Y	Y	N

(a) Y symbol means "yes"; N symbol means "no"; ^ symbol means not checked.

With one exception, all site laboratories tested the conductivity standard before testing their deionized water. The purpose of doing this is to establish a correction factor (for the cell and temperature) for use with subsequent measurements at the same temperature.

All site operators asked said they used distilled water to rinse the electrode during the analysis and before storing it. All sites queried also rinse the conductivity cell with sample before refilling it with sample and taking the final reading.

Almost all field laboratory operators correct their conductivity readings to 25°C (the standard temperature) before recording the value. Two sites in West Virginia did not.

All site operators and laboratory analysts measured sample conductivity then sample pH. This is the prescribed order. The only recommendation is that sites seek uniformity in the volume of sample required for conductivity measurements. On a within-state or within-agency basis, the data sets may be consistent. However, when the entire State-Operated Network data base is considered, some sites may not have as many analyses of low-volume events due to the larger amounts used in the field analyses. In general, the central laboratory, not the local laboratory, should be given priority in receipt of samples.

pH. Table 11 lists five items concerning pH measurement techniques. A wide variety of electrode storage solutions are still in use. The use of deionized water is acceptable, but probably shortens the life of the electrode. All sites determined pH with the electrode's electrolyte fillhole open. It should be open during calibration and analysis to allow free flow of electrolyte through the junction. At all but one site, the pH electrode was rinsed with deionized water, operators handled the electrode properly, and all but one site (Warwood, WV) used the two-buffer calibration technique with slope adjust.

Results of Field Site Analysis of Simulated Precipitation

Each field laboratory was asked to analyze a performance audit solution for conductivity and pH. These solutions were prepared by dilution of EPA-supplied performance test solutions; the audit value is designated by EPA. Designated quality limits are $\pm$ 0.1 unit for pH and $\pm$ 4 μS/cm for conductivity. Table 12 summarizes the findings.

TABLE 11. pH MEASUREMENT TECHNIQUE

Site Name	Electrode Storage Medium*	Fill Hole Open?	Electrode Rinsed With DI Water?	Rinse with Sample?	Electrode Handling Good?
Mobile AL	stor. sol.	Y (a)	Y	N (a)	Y
Tallassee AL	stor. sol.	Y	Y	Y	Y
Georgetown DE	^ (a)	^	^	^	Y
Lums Pond DE	^	^	^	^	Y
Hiawassee GA	dis. water	Y	Y	N	Y
Summerville GA	pH 4	Y	Y	N	Y
Grant Forest GA	pH 4	Y	Y	N	Y
Dawsonville GA	pH 4	Y	Y	N	Y
McDuffie County GA	pH 4	Y	Y	N	Y
Waycross GA	pH 4	Y	Y	N	Y
Grayson Lake KY	stor. sol.	Y	N	Y	Y
Mammoth Cave KY	stor. sol.	Y	Y	Y	Y
Rosepine LA	dis. water	Y	Y	N	Y
Chase LA	stor. sol.	Y	Y	N	Y
Carville LA	dis. water	Y	Y	N	Y
Rocky Gap MD	pH 4	Y	Y	N	Y
The Elms MD	pH 7	Y	Y	Y	Y
University MS	pH sol.	Y	Y	Y	Y
Cape Romain SC	stor. sol.	Y	Y	N	Y
Congaree Swamp SC	stor. sol.	Y	Y	N	Y
Delta SC	stor. sol.	Y	Y	N	Y
Long Creek SC	stor. sol.	Y	Y	N	Y
Custer State Park SD	dis. water	Y	Y	Y	Y
Pierre SD	pH 4	Y	Y	Y	Y
Center Hill TN	stor. sol.	Y	Y	N	Y
Charleston WV	dis. water	Y	Y	Y	Y
Greenbrier WV	dis. water	Y	Y	Y	Y
Warwood WV	dis. water	Y	Y	Y	Y
New Manchester WV	dis. water	Y	Y	Y	Y

* pH 4 and pH 7 refer to buffer solutions.

(a) Y symbol means "yes"; N symbol means "no"; ^ means not checked.

TABLE 12. RESULTS OF FIELD SITE ANALYSIS OF SIMULATED PRECIPITATION

Site Name	pH (pH units)			Conductivity (umhos/cm)			
	Site	Audit	Diff*	DI H2O	Site	Audit	Diff*
Mobile AL	3.83	3.84	-0.01	7.97	79.70	77.10	2.60
Tallassee AL	3.85	3.80	0.05	1.3	72.1	77.1	-5.00
Georgetown DE	4.25	4.30	-0.05	0.9	23.6	24.0	-0.40
Lums Pond DE	4.25	4.30	-0.05	0.9	23.6	24.0	-0.40
Hiawassee GA	4.34	4.31	0.03	5.5	23.1	24.1	-1.00
Summerville GA	4.11	4.31	-0.20	7.6	27.2	24.1	3.10
Grant Forest GA	4.32	4.31	0.01	2.8	22.4	24.1	-1.70
Dawsonville GA	4.37	4.31	0.06	2.1	22.0	24.1	-2.10
McDuffie County GA	4.37	4.31	0.06	1.7	22.4	24.1	-1.70
Waycross GA	4.40	4.31	0.09	1.5	22.1	24.1	-2.00
Grayson Lake KY	4.37	4.31	0.06	2.3	24.2	24.1	0.10
Mammoth Cave KY	4.38	4.31	0.07	0.4	20.3	24.1	-3.80
Rosepine LA	4.31	4.31	0.00	2.9	22.8	24.1	-1.30
Chase LA	3.80	3.80	0.00	2.1	74.9	77.1	-2.20
Carville LA	4.27	4.31	-0.04	1.7	24.1	24.1	0.00
Rocky Gap MD	4.33	4.30	0.03	1.0	22.3	24.0	-1.70
The Elms MD	4.39	4.31	0.08	0.4	22.3	24.1	-1.80
University MS	3.84	3.80	0.04	2.7	77.8	77.1	0.70
Cape Romain SC	4.22	4.31	-0.09	1.4	24.2	24.1	0.10
Congaree Swamp SC	4.22	4.31	-0.09	1.4	24.2	24.1	0.10
Delta SC	4.22	4.31	-0.09	1.4	24.2	24.1	0.10
Long Creek SC	4.22	4.31	-0.09	1.4	24.2	24.1	0.10
Custer State Park SD	4.23	4.31	-0.08	4.8	22.0	24.1	-2.10
Pierre SD	4.35	4.31	0.04	1.45	24.00	24.10	-0.10
Center Hill TN	4.35	4.31	0.04	0.8	24.6	24.1	0.50
Charleston WV	4.26	4.31	-0.05	1.8	24.3	24.1	0.20
Greenbrier WV	4.26	4.31	-0.05	1.8	24.3	24.1	0.20
Warwood WV	4.28	4.31	-0.03	2.6	23.3	24.1	-0.80
New Manchester WV	4.28	4.31	-0.03	2.6	23.3	24.1	-0.80

* Difference = Site Value - Audit Value

Only one field laboratory had pH results varying by more than 0.1 unit from the designated value. The average absolute variation was 0.078 ± 0.07 unit. Only one laboratory had conductivity values varying by more than ± 4 μS/cm from the expected value. The average absolute difference was 1.30 ± 1.24 μS/cm.

It is concluded that with these two exceptions, the field laboratories are doing an acceptable job of determining conductivity and pH of precipitation samples.

Results of Check of Balance

Most of the site laboratories use a triple-beam solution balance to determine the mass of sample collected each week. The laboratories in West Virginia use volumetric glassware to determine the mass after correction for density at varying temperatures.

The balances were tested for accuracy by having the analyst weigh a series of Belfort rain gauge calibration discs of known weight. Each disc weighs about 823 grams. Figure 6 shows that at loadings of one, two, and three weights, the balances are usually accurate to within ± 1 gram. At a loading of four weights (approximately 3,293 g), the majority of the balances are accurate to ± 5 g. These are acceptable results. One balance was out of agreement between 5 and 10 grams at load levels 1647 g and 2471 g. Two balances were out of tolerance by 5 to 10 grams at load levels of 3293 g and 4116 g. These balances should be serviced or replaced.

It is again suggested that the West Virginia laboratories use solution balances to determine sample mass. The process is quicker and not subject to contamination and sample crossover.

SITING CRITERIA

Each collection location was classified as either urban-influenced (refer to Appendix A for criteria) or regionally-located (refer to Appendix B for criteria). All sites in this report are evaluated according to one of these classifications.

Urban-Influenced Sites

Four of the 29 locations in the network are considered to be urban-influenced sites. Siting exceptions for these four are listed and discussed below.

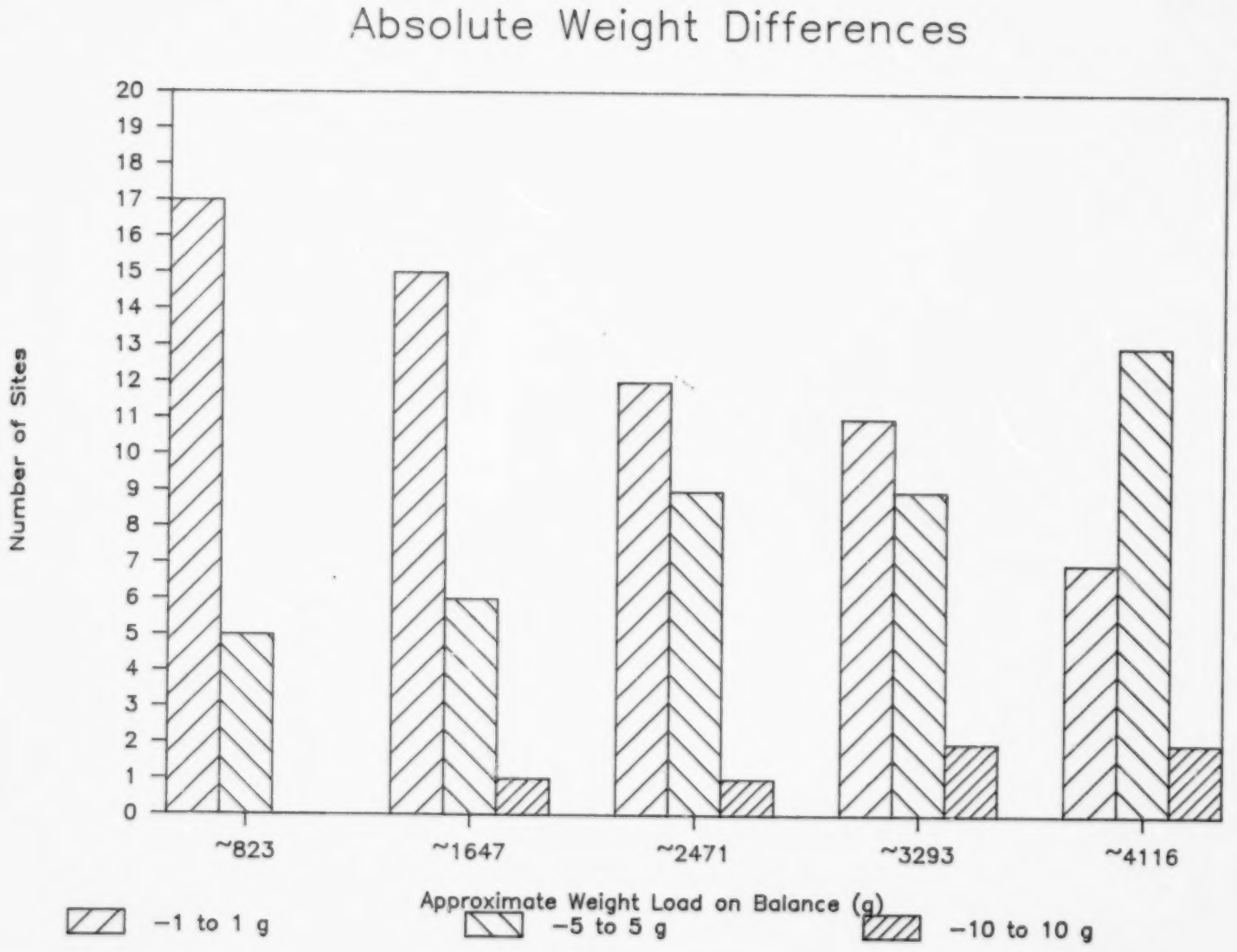

Figure 6. Balance Performance Audit Results.

Carville. The following criteria were not satisfied:

- The rain gauge and precipitation collector are placed within 3 m of each other.
- The collector's wet-side bucket faces east rather than west.
- A parking lot used for tractor storage is less than 25 m from the collector.
- Based on the USGS map, numerous oil and natural gas fields are within 5 km of the site. This distance barely satisfies the criterion for separation from a major source.

Charleston. The following criteria were not satisfied:

- The collector is quite near an air conditioning unit that occupies approximately 30° of arc as viewed from the collector. However, the unit is lower than the collector.
- The collector is approximately 10 m from the edge of a frequently traveled city street. However, the collector is on a roof abut 8 m above the roadway level. This positioning may diminish the influence of gaseous and particulate emissions.
- There is no collocated rain gauge at this site.

New Manchester. The following criteria were not satisfied:

- The collector is mounted on the roof of a monitoring shelter, approximately 14 feet above ground level. The collector is located at the edge of the roof. The slope of the ground in the vicinity of the site exceeds 20° from the horizontal.
- A meteorological tower (TV mast) projects onto the collector at greater than a 45° angle.
- A country road passes within 25 m of the collector to the north. The collector and the roadbed are at approximately the same level.
- Although the site meets the distance criterion for separation from a major source, it should be noted that a coal-fired power plant is approximately 4.5 km from the site.
- There is no collocated rain gauge at the site.

Warwood (Wheeling). The following criteria were not satisfied:

- The collector is closer than 50 m to a heavily traveled road (WV Route 2). However, since the collector is located on the roof of a two-story building, the effects of splash and dust from the road are expected to be minimal.

Warwood (Wheeling). (continued)

- Although the distance criterion is met, it should be noted that this collection site is near coal-fired power plants at distances of 5 km or greater.
- There is no collocated rain gauge at the site.

Regionally Located Sites

Of the 29 locations in the network, 25 are considered to be regionally-located. Twenty-one of these 25 sites had one or more siting criteria exceptions. These exceptions are listed and discussed below on a site-by-site basis. No exceptions to siting criteria were noted at the Dawsonville, B. F. Grant, McDuffie, and Waycross, GA locations.

Mobile. The following criteria were not satisfied:

- The slope of the land surrounding the site is more than 20° from the horizontal within a radius of 30 m.
- The rain gauge and precipitation collector are not separated by the prescribed 5 m.

Tallassee. The following criteria were not satisfied:

- A dead end street runs approximately 50 m east of the collector. Since traffic is low, this is not considered to be a significant problem.
- The gauge and collector are separated by less than 5 m.
- The collector's sensor faces south, not north as prescribed.

Georgetown. The following criteria were not satisfied:

- A highway (DE Route 9) is approximately 40 m from the collector.
- Although the distance requirement is satisfied, it should be noted that a chicken house is approximately 30 m from the sampler.

Lum's Pond. The following criteria were not satisfied:

- A radio tower (30 m height) is approximately 25 m from the collector.
- A one-story park maintenance building is less than 20 m from the collector and occupies greater than a 30° arc as viewed from the collector.

Hiawassee. There was one exception to siting criteria:

- The gauge and collector are not separated by 5 m.

McDuffie. There was one exception to siting criteria:

- The gauge and collector are not separated by 5 m.

Summerville. The following criteria were not satisfied:

- The gauge and collector are separated by only 1.9 m rather than the desired 5 m.
- The distance from the site to the nearest concentration of animals (hog barn, in this case) is 125 m. The prescribed minimum separation is 500 m.

Grayson Lake. There was one exception to siting criteria:

- The collector's wet-side bucket faces north rather than to the west.

Rosepine. The following criteria were not satisfied:

- The precipitation collector is located within 3 m of the rain gauge.
- Grazing cattle can come as close as 6 m to the collector.

Chase. The following criteria were not satisfied:

- The precipitation collector is located within 3 m of the rain gauge.
- The site is within 0.6 km of a major thoroughfare and not separated by the desired 2 km.

Rocky Gap. The following criteria were not satisfied:

- A steep, upward slope occurs to the south of the sampler; it is the earth-retaining wall of a small pond. The rain gauge and sampler are located on a platform that raises them above the retaining wall.
- The separation distance between the rain gauge and the collector is slightly less than 5 m.

The Elms. The following criteria were not satisfied:

- The collector and rain gauge are separated by 3.3 m, somewhat less than the desired 5 m apart. The collector and rain gauge openings are not at the same height above ground.

The Elms. (continued)

- The site is located approximately 250 m east of the Chesapeake Bay, a source of salt spray.

University. The following criteria were not satisfied:

- The angle of projection of trees to the east on the rain gauge is greater than 45°.
- An asphalt plant (industrial source) is located 5 to 6 km to the west.
- Vegetation within a 10 m radius of the collector was taller than the maximum specified height of 0.6 m.

Cape Romain. The following criteria were not satisfied:

- The collector and tipping bucket rain gauge are separated by 2 m. They are both on the top of a platform, approximately 3 m above ground level.
- Collocated equipment (high volume sampler) is located 2 m from the collector.
- The collector is located within 2 m of a small shed and water storage tank. Chain-link and wooden slat fences are located on a north-to-south line approximately 2 m from the collector. The collector opening is at a height above all these structures.
- A maintenance building and parking lot are within 35 m of the collector. Vehicles are stored within 10 m of the collector.
- The brackish Sewee Bay is within 500 m of the collector.

Congaree Swamp. The following criterion was not satisfied:

- The tipping bucket rain gauge and collector are located within 1 foot of each other. Both are atop a 2.8 m height platform to prevent damage from seasonal flooding in the swamp.

Delta. The following criteria were not satisfied:

- A small trailer is ~ 7 m from the collector; an instrumentation shelter is 5 m away.
- A transportation source, a railroad line, is less than 80 m away.

Long Creek. There is one exception to siting criteria:

- The collector and tipping bucket rain gauge are separated by less than 5 m.

Pierre. The following criteria were not satisfied:

- The collector and rain gauge are separated by less than 5 m.
- The collector's wet-side bucket is oriented to the northwest rather than to the west.

Custer State Park. There was one exception to the siting criteria:

- There is a possibility that deer can approach to within 20 m of the collector. There is a fence.

Center Hill. The following criteria were not satisfied:

- The tipping bucket rain gauge was on a tower ~ 7 m above the precipitation collector. They are not at the same height above ground.
- The collector's wet-side bucket faces the north, rather than the west.

Greenbrier. The following criteria were not satisfied:

- The ground slope meets the criterion for all directions except the east. Here the ground drops off quickly at a point about 8 m from the collector, and the cliff descends to the valley below. Thus the collector is too near an edge. It should be at least 30 m away.
- The collector is on top of a monitoring shelter about 4 m above the ground.

Discussion

It is difficult to know what effect small variations from stipulated siting criteria may have on the physical and chemical data base of a precipitation site. Of necessity, many of the criteria are somewhat arbitrary and are often based on best judgment or on those criteria successfully employed by other networks. Different networks may allow varying criteria to be applied and still meet objectives. Discussed below are the most important of the siting criteria exceptions in this network and the authors' reasoning for recommending change.

One of the most important siting criterion is placement of the collector and rain gauge so that their sample catch is not obstructed. Several collectors or gauges are in fact obstructed by trees, towers, or nearby equipment. This is

noted as either a violation of the 30° arc criteria or the 45° angle of projection criterion. Trees or structures may affect the sample catch efficiency and/or allow precipitation that has been in contact with the tree or structure to enter the collector and affect the chemistry. For these reasons, it is recommended that the samplers be repositioned or the obstructions removed if possible.

Another important siting criterion is adequate distance from major sources of air pollution. Several of the sites are near sources (power plants, asphalt plants, etc.) even though the separation distance may nominally meet the criterion. It is recommended that the presence of sources and their distance and direction from the site be noted and that these notes accompany the data so that users will be aware and interpret the data base accordingly. Similarly, information concerning those sites that are undesirably near roads should be given.

Two sites are near animal populations (cattle, hogs). This fact should be recognized during data analysis. Ammonia (ammonium) concentrations may be higher than usual and cause pH values to be elevated. If possible, the collector should be moved to a new location.

Another two sites are near bodies of salt water. The data user must be made aware of this as higher than expected values of sodium and chloride will occur during episodes of salt spray.

Discrepancies in the horizontal separation of the precipitation collector and rain gauge are not considered to be a large problem. In almost all cases, the two are separated by at least 3 m, and in many cases, the rain gauge is of the tipping bucket variety. These small gauges offer less obstruction to the collector than do the larger weighing type gauges. Probably of more importance is the vertical separation of the orifices of the precipitation collector and rain gauge. In a couple of cases, the gauge is considerably higher or lower than the collector. These gauges should be repositioned to the height of the collector.

This network is somewhat unique in that it seems that state agencies have set up their sites with different objectives in mind. One state wants to collect precipitation in predominantly urban areas; another stresses rural, forested areas. For these reasons, the user of the overall network data base should be made aware of these variations and select and interpret the data accordingly.

SECTION 7
COMPARISON OF 1987 AND 1986 AUDIT RESULTS

In order to assess improvements in network siting and operations, results from selected categories from visits to 29 SON sites made in the 1987 round of the site visitation program were compared to results for the same categories for the same sites from the 1986 round. (Note that two new sites were visited in 1987 that were not on-line during the first round of visits.) Results from the following categories are compared: siting criteria, performance of the precipitation collector and rain gauge, and results of field determinations of pH and conductivity. These are discussed below.

SITING CRITERIA COMPARISONS

Table 13 lists three siting criteria relating to precipitation collector placement and five criteria relating to site surroundings.

With respect to the sample collector's location, five of twenty-nine sites had the wet-side bucket oriented towards a direction other than the prescribed west. This criteria was not reviewed in the 1986 visits. The collector-gauge separation, which is supposed to be 5 meters, is closer than that in eight cases in 1986 and in 14 cases in 1987. It is not believed that the equipment was moved closer, only that the site visitors made more exact measurements in 1987 than in 1986. Two sites had their rain gauges and collectors at quite different heights above the ground. This remained unchanged.

With respect to site surroundings, only one site had allowed the grass to grow taller than two feet within a 30 m radius of the collector. There were no instances noted in 1986. Four sites that had towers, trees, or buildings too close to the collector in 1986 continued to show this condition in 1987. The number of sites with parking lots, animals, and transit sources closer than the prescribed distances also remained virtually unchanged from 1986 to 1987.

It can be concluded that few sites were able to take action to change siting characteristics. Most of the variations are expected to have little, if any, effect on the sample chemistry or collection efficiency. Among the most important criteria to meet are those relating to obstructions (45° angle of

TABLE 13. COMPARISON OF RESULTS OF SITING CRITERIA: ROUND 1 AND ROUND 2 VISITS

Siting Criteria	Number and Percent of Sites Not Meeting Criteria	
	Round 1[a] (1986)	Round 2[a] (1987)
Collector Location		
• Wet bucket orientation	not reviewed	5 (17%)
• Collector-gauge separation	8 (30%)	14 (48%)
• Collector-gauge heights	2 (7%)	2 (7%)
Site Surroundings		
• Vegetation greater than 2 feet in height within 30 m	0 (0%)	1 (3%)
• 45° angle violation from tree or obstruction	4 (15%)	4 (14%)
• Storage or parking lots < 100 m	2 (7%)	2 (7%)
• Animals < 30 m	1 (4%)	2 (7%)
• Transit sources < 100 m	4 (15%)	5 (17%)

[a] Twenty-seven sites in Round 1; twenty-nine sites in Round 2.

projection and structure crossing a 30° cone drawn from the collector), animal populations, and vehicular traffic. These criteria exceptions should be corrected.

COLLECTOR AND RAIN GAUGE COMPARISONS

Precipitation Collector

Five installation and operation criteria for the precipitation collector were compared. Table 14 summarizes the findings.

The most noticeable improvement in meeting criteria has to do with lid-seating where all sites met the criteria in Round 2. Bucket and liner cleanliness and condition has also substantially improved. More sites also now meet collector height siting requirements and the few (6) that do not comply with this criterion have special reasons for not doing so (located on urban roofs, located on platforms to avoid obstructions, flooding, etc.). Little improvement has been made in meeting sensor and heater performance criteria, however. It is desirable that all sites have collectors with similar opening and closing characteristics, although the extent to which such characteristics affect collection data is unknown.

Rain Gauge

Four items were compared concerning the rain gauge. First, was the gauge in calibration? More gauges were in calibration over the full range (0 to 12 inches) in the second round than in the first which represents a major improvement in gauge accuracy. In both rounds, most of the gauges out-of-calibration were only so at depths greater than 6 inches. In addition, more sites had rain gauges, event markers, and working event markers during Round 2 than Round 1. The presence of accurate gauges and working event markers will facilitate the estimation of network capture efficiencies.

CONDUCTIVITY AND pH MEASUREMENT COMPARISONS

The twenty-nine sites were compared for accuracy of measurement of conductivity and pH. Data in Table 15 shows an improvement in the number of sites that were able to determine the conductivity of a simulated precipitation sample to within $\pm$ 4 μS/cm and pH to within $\pm$ 0.1 pH unit of the designated value. Of

TABLE 14. COMPARISON OF PRECIPITATION COLLECTOR AND RAIN GAUGE INSTALLATION AND PERFORMANCE: ROUND 1 AND ROUND 2 VISITS

Criteria	Number and Percentage of Sites Not Meeting Criteria[a]		Round 1 Sites Uncorrected by Round 2
	Round 1 (1986)	Round 2 (1987)	
Precipitation Collector			
• Wet bucket cover seats poorly	2 (7%)	0 (0%)	0
• Sensor performance	6 (22%)[d]	4 (14%)[e]	0
• Standard height[b]	11 (41%)	6 (21%)	6
• Bucket orientation correct	17 (63%)	14 (48%)	11
• Sensor heater			
a) doesn't heat	5 (19%)	5 (17%)	4
b) heats continuously	8 (30%)	8 (28%)	8
c) too hot	2 (7%)	3 (10%)	2
d) too cold (< 50°C)[c]	10 (37%)	9 (31%)	9
• Liner condition poor	9 (33%)	3 (10%)	1
Rain Gauge			
• Gauge out-of-calibration[f]	9 (64%)	3 (19%)	3
• Site without recording rain gauge	6 (22%)	4 (14%)	4
• No event marker connected to precipitation collector[f]	7 (33%)	5 (21%)	5
• Event marker not working[g,h]	4 (28%)	3 (15%)	0

a Of 27 collectors that were in operation at the time of both Round 1 and Round 2 visits.

b All collectors not meeting standard height were on elevated platforms, shelter, or building roofs.

c This does <u>not</u> include those site sensors that which were not heating at all.

d Note that 11 sensors could not be tested during the first round. All but 3 sensors were tested in the second round.

TABLE 14. COMPARISON OF PRECIPITATION COLLECTOR AND RAIN GAUGE INSTALLATION AND PERFORMANCE: ROUND 1 AND ROUND 2 VISITS (CONTINUED)

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[e] These appear to be due to differences in rain gauge design rather than malfunction of sensor.

[f] Tipping bucket style rain gauges were not checked. Two other sites were not checked.

[g] This does not include sites without recording rain gauges.

[h] This does not include sites without event markers.

TABLE 15. COMPARISON OF CONDUCTIVITY AND pH MEASUREMENTS: ROUND 1 AND ROUND 2 VISITS

Criteria	Number and Percentage of Sites Not Meeting Criteria		Sites Which Did Not Meet Criteria in Both Rounds
	Round 1 (1986)	Round 2 (1987)	
Conductivity within ± 4 μS/cm	3 (11%)	1 (3%)	0
pH within ± 0.1 pH unit	2 (7%)	0 (0%)	0

the three sites that were out-of-tolerance on conductivity measurements in Round 1 (1986), none repeat in Round 2 (1987). Of the two sites out-of-tolerance in measuring pH, none repeat in Round 2.

SUMMARY

In general, substantial improvements have been made in site pH and conductivity measurements, collection bucket lid seal and liner cleanliness, and collector height criteria. Items for which problems continue include collector orientation and collector sensor and heater performance. Several sites need to have obstructions removed or collectors repositioned to satisfy siting criteria.

SECTION 8
REFERENCES

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3. Topol, L. E., et al. Quality Assurance Manual for Precipitation Measurement Systems. Part I. Quality Assurance Manual. Environmental Protection Agency Publication No. EPA-600/4-82-042a. Revised January 1985.

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APPENDIX A

URBAN SITING CRITERIA

SITE INFLUENCES

1. The steepest slope of the ground within 30 m (98 ft.) of the precipitation collector and rain gauge should be less than 20 degrees and should be less than or equal to slopes typical of the general terrain unless the site is on a hilltop. The slope should then be less than 30 degrees. The openings of the collector and gauge should be level and at the same height above ground, within 0.5 m (1.6 ft.). The separation distance between collector and gauge should be at least 5 m (16 ft.) and no more than 30 m (98 ft.) unless they are mounted on a platform in high snowfall areas.

2. If the collector must be located on a rooftop of a building, apply the same criteria for obstructions as if the site were at ground level. The roof should be approximately the same height as those of surrounding buildings, level, and its surface free of dusty materials. Buildings of one to three stories in height are preferred. The collector should be located near the center of the roof and as far as possible from exhaust or inlet vents, chimneys, or overhead wires. Be cognizant of chimneys, exhausts, etc. on adjacent buildings.

3. Surrounding vegetation, land features, and structures within 500 m (1,640 ft.) of the site should be typical of those in the urban area. The height of the ground cover should be no greater than 0.6 m (2 ft.) within a circle of 10 m (33 ft.) radius surrounding the collector.

4. No object (overhead wire, tree, building, etc.) should project onto the collector at an angle greater than 45 degrees.

5. In a wooded setting, the site should be located in a clearing at least 30 m (98 ft.) from the woodline.

6. The distance from the collector to the nearest solid structure (house, shed, wall, etc.) should be great enough so that the object occupies less than 30 degrees of arc viewed from the collector. The angle of projection from the top of a solid structure should not exceed 15 degrees.

LOCAL INFLUENCES

7. The distance from the site to the nearest source, such as a landfill or sewage treatment facility, should be at least 100 m (328 ft.).

8. The distance from the site to open surface storage of agricultural products, fuels, or chemicals should be at least 100 m (328 ft.).

9. The distance from the site to sources of fugitive dust such as a cement plant should be at least 200 m (656 ft.).

10. If the site is at ground level, the nearest large parking area (> 20 vehicles), smaller parking area with frequent use, or vehicle and equipment service area should be at least 30 m (98 ft.) from the collector.

11. The nearest regularly traveled road carrying < 120 vehicles/hour (24 hour average) should be at least 30 m (98 ft.) from the collector. A driveway, traveled only to reach the site, is an exception; however, it should be no nearer than 10 m (33 ft.) to the collector.

12. The distance from the site to the nearest state or secondary road carrying over 120 vehicles/hour (24 hour average) should be at least 50 m (164 ft.). The collector should not be located alongside heavily traveled city streets at ground level.

13. Distance from the collector to oceans or salt water bodies which may contribute significant salt spray should be at least 2 km (1.2 miles).

14. The distance from the site to the nearest major industrial source, such as a coal or oil burning power plant or foundry should be at least 3.2 km (2 miles).

15. The distance from the site to the nearest interstate highway, major thoroughfare, major airport, or railroad complex should be at least 1 km (0.6 mile).

APPENDIX B

REGIONAL SITING CRITERIA

SITE INFLUENCES

1. The steepest slope of the ground within 30 m (98 ft.) of the precipitation collector and rain gauge should be less than 20 degrees and should be less than or equal to slopes typical of the general terrain unless the site is on a hilltop. The slope should then be less than 30 degrees. Ideally, the slopes should be less than 5 degrees. The collector and rain gauge should be mounted at ground level or on platforms of small surface area and of height generally no more than 1 m (3.3 ft.). The openings of the collector and gauge should be level and at the same height above ground, within 0.5 m (1.6 ft.). The separation distance between collector and gauge should be at least 5 m (16 ft.) and no more than 30 m (98 ft.) unless they are mounted on a platform as is required in high snowfall areas.

2. The distance to collocated equipment should be at least 5 m (16 ft.).

3. Surrounding vegetation within 500 m (1,640 ft.) of the site should be typical of vegetation in the region. The height of the ground cover should be no higher than 0.6 m (2 ft.) within a circle of 10 m (33 ft.) radius surrounding the collector.

4. In a forest setting, the site should be located in a clearing at least 30 m (98 ft.) from the woodline. In no case, should the angle of projection of a tree onto the collector or rain gauge rim be greater than 45 degrees.

5. The distance from the collector to the nearest solid structure (house, shed, wall, etc.) should be great enough so that the object occupies less than 30 degrees of arc viewed from the collector. The angle of projection from the top of a solid structure should not exceed 15 degrees.

6. The distance from the site to the nearest grazing domesticated animals should be at least 20 m (66 ft.).

7. The distance from the site to the nearest cultivated field should be at least 20 m (66 ft.).

LOCAL INFLUENCES

8. The distance from the site to the nearest source, such as a landfill or sewage treatment facility, should be at least 100 m (328 ft.).

9. The distance from the site to open surface storage of agricultural products, fuels, or vehicles should be at least 100 m (328 ft.).

10. The distance from the site to sources of fugitive dust (such as a cement plant or granary) should be at least 500 m (1,640 ft.).

11. The distance from the site to the nearest large concentration of animals, such as dairy feedlots, should be at least 500 m (1,640 ft.).

12. The nearest parking lot containing fewer than 10 vehicles, and where traffic movement is limited to a few brief episodes daily (people coming to and leaving work) should be at least 75 m (246 ft.) from the collector.

13. The nearest large parking area (> 20 vehicles), smaller parking area with frequent use, or vehicle and equipment service area should be at least 100 m (328 ft.) from the collector.

14. The nearest regularly traveled road carrying less than 30 vehicles/hour (24 hour average) should be at least 50 m (164 ft.) from the collector. A driveway or jeep trail, traveled only to reach the site, is an exception; however, it should be no nearer than 10 m (33 ft.) to the collector.

15. The distance from the site to the nearest state or secondary road carrying over 30 vehicles/hour should be at least 100 m (328 ft.).

REGIONAL INFLUENCES

16. The distance from the collector to oceans or salt water bodies which may contribute significant salt spray should be at least 2 km (1.2 miles).

17. The distance from the site to the nearest small community (100-1,000 pop.) should be at least 0.75 km (0.5 mile).

18. The distance from the site to the nearest urban area (1,000-10,000 pop.) should be at least 1 km (0.6 mile).

19. The distance from the site to the nearest urban area (10,000-75,000 pop.) should be at least 5 km (3 miles).

20. The distance from the site to the nearest urban area (> 75,000 pop.) should be at least 20 km (12 miles).

21. The distance from the site to the nearest major industrial source, such as a coal or oil burning power plant, foundry, chemical plant, etc., should be at least 10 km (6 miles).

22. The distance from the site to the nearest interstate highway, major thoroughfare, major airport, or railroad complex should be at least 2 km (1.2 miles).